ETCHED CIRCUIT FOR LIGHTNING PROTECTION

BACKGROUND OF THE INVENTION

The invention relates to the lightning protection of transmitters in a transmission system.

The function of lightning protection calls for a high-pass filter because the lightning signal is a low-frequency signal. Figure 1 shows a lumped-element lightning protection system. It has two induction coils 11 and 12, each grounded. The first induction coil 11 is connected directly to the transmission antenna. It attenuates low frequencies. A capacitor 13 is placed between these two induction coils 11 and 12. The capacitor 13 filters the high frequencies. The second induction coil 12 is optional. It improves the attenuation.

Lightning protection circuits of this kind are made of linear, discrete components. However, they are very bulky and are complicated to manufacture

SUMMARY OF THE INVENTION

The present invention can be used to obtain an etched circuit comprising a lightning protection function of this kind, thus reducing space requirement and providing for easier and lower-cost manufacture (because, *inter alia*, there are fewer components).

An object of the invention is an etched circuit with lightning protection comprising at least one main line connected to a connector adapted to the output of the transmission antenna of the transmission system working at a fixed frequency f_0 or in a narrow frequency band Δf_0, the circuit comprising a capacitor, wherein said circuit comprises at least one first line with a length l_1 and a width that may or may not be constant, connected to said connector and terminated by a short-circuit that is open-circuited with respect to the main line.

The circuit proposed by the invention is furthermore used to filter the second harmonic.

Another object of the invention is a method for the manufacture of an etched circuit with lightning protection comprising the etching of the lines and of the capacitor of said etched circuit on the base of said circuit, the depositing of a film of conductive material and, if necessary, the scraping

away of the excess conductive material in order to retain only the conductive material that has been deposited in the etching.

The invention furthermore proposes the application of the above-defined etched circuit with lightning protection to the filtering of the second harmonic $2f_0$ and the third harmonic $3f_0$.

BRIEF DESCRIPTION OF THE DRAWINGS

The characteristics and advantages of the invention shall appear more clearly from the following description, given by way of an example, and from the appended figures of which:

- Figure 1 shows a lumped-element lightning protection circuit according to the prior art
- Figure 2 shows the lightning protection function on an etched circuit according to the invention,
- Figure 3 shows a lumped-element harmonic filtering circuit according to the prior art,
- Figure 4 shows the harmonic filtering function on an etched circuit according to the prior art,
- Figure 5 shows the common function of lightning protection and of filtering of the harmonics $2f_0$ and $3f_0$ according to the invention,
- Figure 6a and 6b, is a curve showing the filtering of the harmonics by means of the filter of figure 5, with figure 6b corresponding to the optimized filter.

MORE DETAILED DESCRIPTION>

If the lumped-element lightning protection circuit is expressed in distributed constants, as illustrated in figure 2, the inductors 11 and 12 are replaced by conductive lines 21 and 22 etched on a quarter wavelength at the frequency f_0 used. The lines 21 and 22 are each terminated by a short-circuit. The main line and the capacitor 23 are placed between these two lines 21 and 22.

Let us take the example of a circuit of this kind with 22-nH inductors and a 47-pF capacitor. For 1000 V injected into this circuit, only 50 V remains at output.

Given that, at the at the frequency f_0 used, a quarter-wave line that is shorted at one end is the equivalent of an open circuit at its other end for this

same frequency, the two lines 21 and 22 are open-circuited with respect to the main line at the frequency f_0.

At the second harmonic $2f_0$, this same line is therefore the equivalent of a short-circuit. The lightning protection on the etched circuit in the diagram proposed in figure 2 therefore represents an excellent $2f_0$ rejector (namely a filter stopping said frequency $2f_0$).

The first line 21 is therefore used to filter the low frequencies of the lightning signal and reject the second harmonic.

The second line 22 is optional. It improves the attenuation presented.

Hitherto, the lighting protection and harmonic filtering functions were carried out separately by two circuits. The lumped-elements circuit shown in figure 1 provided lightning protection. The harmonic filtering function used to be carried out either by a lumped-element circuit such as the one shown in figure 3 or an etched circuit such as that of figure 4.

Harmonic filtering is a low-pass type of filtering. The circuits of figures 3 and 4 are used to reject the second harmonic $2f_0$ and the third harmonic $3f_0$.

The lumped-element drawing of figure 3 comprises three parallel-connected capacitors 31, 33 and 35, grounded at one of their ends, and two inductors 32 and 34, one inductor between each of the two capacitors. If necessary, inductors may be series-connected with the capacitors 31, 33, 35. They are located between the capacitors and the circuit formed by the two inductors 32 and 34 as indicated in figure 3.

When the above is expressed in terms of distributed constants, we obtain the drawing of figure 4. The inductors are replaced by high-impedance etched lines (having a width smaller than that of a 50-Ohm line) and the capacitors are replaced by copper regions.

The separation of the two functions, namely the lightning protection function and the harmonic filtering function, raises various problems.

First of all, the most commonly-used circuits are the lumped-element circuits of figures 1 and 3, and they are bulky. The distributed-constant circuits too take up much space because the capacitors are etched rectangles of about 1cm² on substrates with high dielectric permittivity (10) and the quarter-wave lines correspond to wavelengths of 2 to 3 cm. These

dimensions are given as an example for frequencies of about one GHz. These dimensions are not negligible, especially in embedded applications.

Again, the series-connection of these two functions on an etched circuit, through the mutual mismatching of the two circuits, may induce impaired performance as compared with the anticipated results of the two separate functions.

Furthermore, it is impossible to position these two functions in an optimal way. Indeed, the lighting protection function as well as the harmonic filtering function should be the first function found after the antenna connector. This is the obvious position for the lightning protection which must protect the entire transmission circuit. However, the harmonic filtering function too must be as far downline as possible from the transmission because there is a risk of the creation of harmonics, especially $2f_0$ and $3f_0$ harmonics, by the antenna switching circuits or by coupling.

The lightning protection circuit according to the invention shown in figure 2 already enabled the filtering of the second harmonic $2f_0$ by using a single circuit to overcome these drawbacks. The presence of a second line in the lightning protection scheme of figure 2 brings the possibility of rejecting the third harmonic too. As can be seen in figure 5, the lengths are then optimized and a matching topology is then simulated to ensure optimum rejection of the two harmonics as well as low loss at the fundamental frequency f_0. This optimization may be obtained by means of an etched circuit simulation tool, for example the ADS tool by AGILENT Technologies.

In figure 5, the optimized circuit for lightning protection and second and third harmonic filtering has two lines 51 and 52 with respective lengths l_1 and l_2 determined, during the simulation, each line being terminated by a short-circuit. These lines 51 and 52 have open stubs 54 and 55. The first line is connected to the output connector of the antenna. A capacitor 53 carries out the high-pass filtering of the lightning protection. It is placed between the two lines on the main line.

Figure 6 shows the first measurements of the filtering of the harmonics in figures 6a and 6b. It represents the amplitude in dB of the signal at output of a lightning protection circuit according to the invention as a function of its frequency. The injected lightning wave is equal to 1000V. It is attenuated to about 50 V.

Figure 6a corresponds to the first measurements with a circuit of the type shown in figure 5. It shows a minimum 30 dB attenuation of the output signal at the two frequencies $2f_0$ and $3f_0$.

Figure 6b corresponds to the measurements obtained after the optimization of this circuit. The optimization gives values of 40 dB for $2f_0$ and 50 dB for $3f_0$.

Hence, lightning protection circuits of this kind, especially the one illustrated in figure 5, enable the filtering of the second harmonic $2f_0$ and of the third harmonic $3f_0$. In particular, these circuits may have a common function of lightning protection and of the filtering of one or more harmonics nf_0 (n being an integer $\geq$ 3).

The circuit of figure 5 is an exemplary embodiment of a circuit comprising a common function of lightning protection and harmonic filtering. More generally, it may be planned to optimize this circuit with the same simulation tools for the rejection of the n first harmonics (n being an integer $\geq$ 3). For this purpose, the circuit may comprise one or more lines terminated by a short-circuit. These lines will have lengths to be determined that are identical or different, widths to be determined that are constant or not constant and identical or not identical. They may or may not comprise one or more stubs whose size has to be determined.

The advantage of such a circuit therefore is the gain in surface area because both functions of lightning protection and harmonic filtering are obtained in a single circuit. Furthermore, this circuit does not call for a large etching surface area like the harmonic filtering circuit of figure 4. Indeed, it only uses lines that can be "wound" or folded. Another advantage of this type of circuit is the possibility of optimizing its performance and reproducibility. Indeed, it provides for a single, fully controlled adaptation. Each function is the first function to be perceived from the antenna.

The manufacture of an etched circuit with lightning protection as illustrated, for example, in figures 2 and 5, comprises the etching of the lines and of the capacitor of said circuit etched on the base of said circuit, the depositing of a film of conductive material and, if necessary, the scraping away of the excess conductive material in order to keep only the conductive material that has been deposited in the etching.

This device can be applied to any field requiring either and/or both of these functions. In fact, transmitters in all communications, broadcasting or identification systems such as IFF, TACAN and DME systems may use such a circuit. When the transmission is made no longer at a fixed frequency but in a frequency band, the performance values accessible in this band have to be verified.